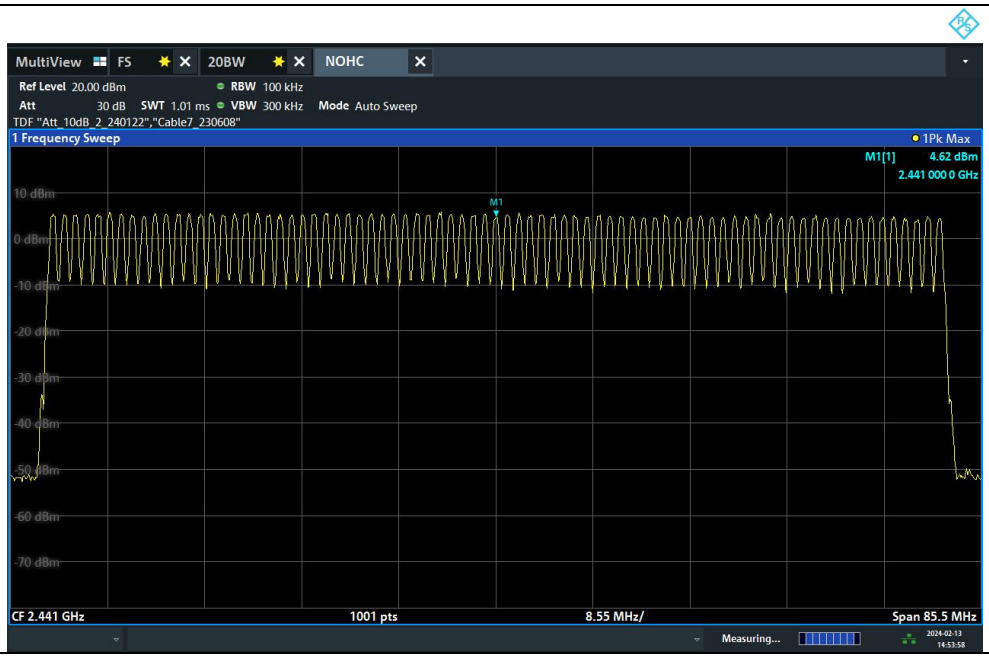
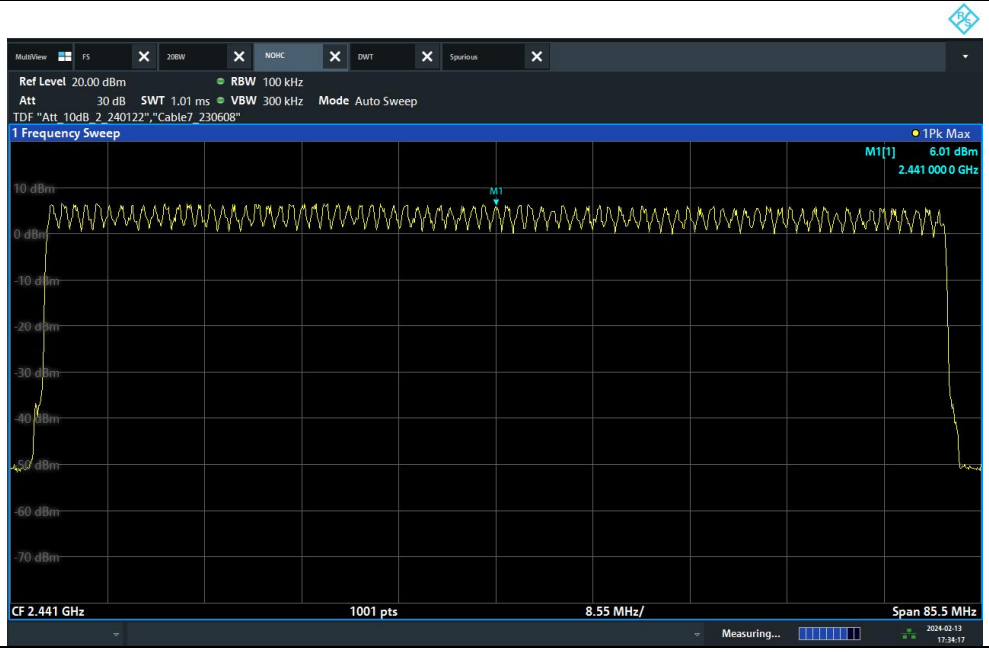
6.5.4 Test Result

Test Plot of Number of Hopping Channels

Number of Hopping Channels
BDR

EDR


6.6 Time of Occupancy (Dwell Time)

6.6.1 Regulation

§15.247(a)(1)(iii) : Frequency hopping systems in the 2400-2483.5 MHz band shall use at least 15 channels. The average time of occupancy on any channel shall not be greater than 0.4 seconds within a period of 0.4 seconds multiplied by the number of hopping channels employed. Frequency hopping systems may avoid or suppress transmissions on a particular hopping frequency provided that a minimum of 15 channels are used.

6.6.2 Test Procedure

The method of measurement used to test this FHSS device is ANSI C63.10-2020.

The EUT shall have its hopping function enabled. Use the following spectrum analyzer settings:

a) Span: Zero span, centered on a hopping channel.
b) RBW shall be ≤ channel spacing and where possible RBW should be set >> 1 / T, where T is the expected dwell time per channel.
c) Sweep: As necessary to capture the entire dwell time per hopping channel; where possible use a video trigger and trigger delay so that the transmitted signal starts a little to the right of the start of the plot. The trigger level might need slight adjustment to prevent triggering when the system hops on an adjacent channel; a second plot might be needed with a longer sweep time to show two successive hops on a channel.
d) Detector function: Peak.
e) Trace: Clear-write, single sweep

Use the marker-delta function to determine the transmit time per hop. If this value varies with different modes of operation (data rate, modulation format, number of hopping channels, etc.), then repeat this test for each variation in transmit time.

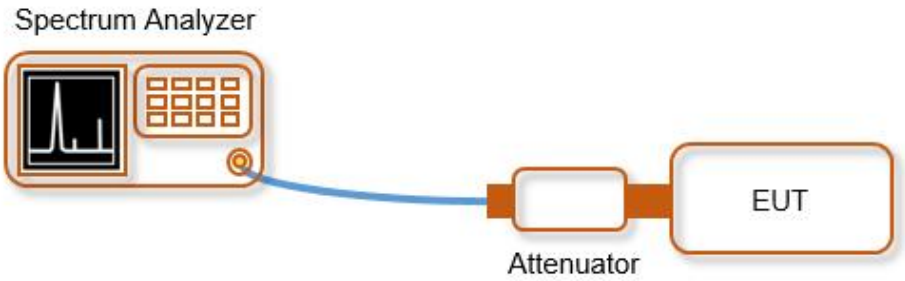
Repeat the measurement using a longer sweep time to determine the number of hops over the period specified in the requirements. The sweep time shall be equal to, or less than, the period specified in the requirements. Determine the number of hops over the sweep time and calculate the total number of hops in the period specified in the requirements, using the following equation:

(Number of hops in the period specified in the requirements) =
(number of hops on spectrum analyzer) × (period specified in the requirements / analyzer sweep time)

The average time of occupancy is calculated from the transmit time per hop multiplied by the number of hops in the period specified in the requirements. If the number of hops in a specific time varies with different modes of operation (data rate, modulation format, number of hopping channels, etc.), then repeat this test for each variation.

The measured transmit time and time between hops shall be consistent with the values described in the operational description for the EUT.

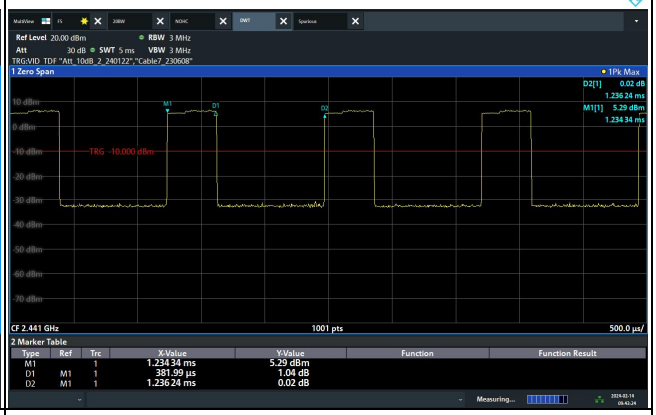
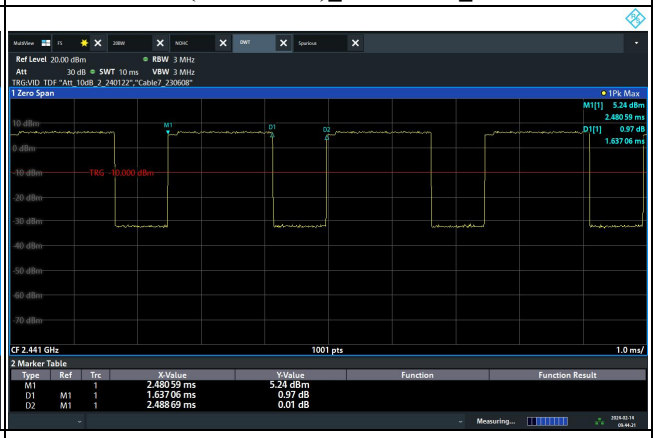
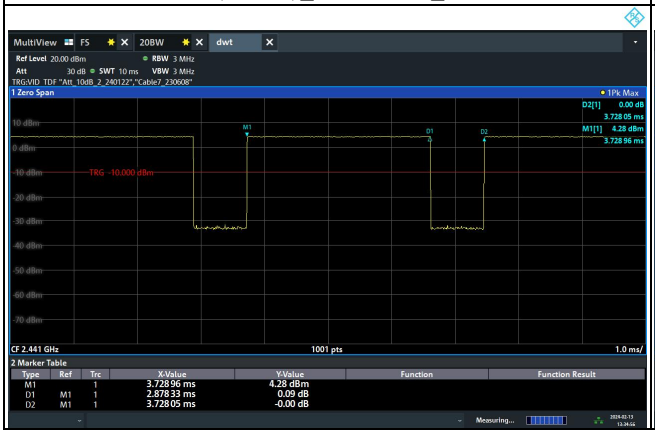
6.6.3 Test Setup



6.6.4 Test Result

Test Mode	Packet Type	Pulse Width [msec]	Hopping Rate [Hop/sec]	Number of Channels	Results [sec]	Limit [sec]
BDR (GFSK)	DH1	0.381	800.00	79	0.122	0.400
	DH3	1.640	400.00	79	0.262	0.400
	DH5	2.878	266.67	79	0.307	0.400
EDR (π/4DQPSK)	2DH1	0.382	800.00	79	0.122	0.400
	2DH3	1.637	400.00	79	0.262	0.400
	2DH5	2.914	266.67	79	0.311	0.400
EDR (8DPSK)	3DH1	0.385	800.00	79	0.123	0.400
	3DH3	1.644	400.00	79	0.263	0.400
	3DH5	2.874	266.67	79	0.307	0.400

Test Plot of Dwell time

Dwell time	
BDR(GFSK)_2 441 MHz_DH1	BDR(π/4DQPSK)_2 441 MHz_DH1
	
BDR(GFSK)_2 441 MHz_DH3	BDR(π/4DQPSK)_2 441 MHz_DH3
	
BDR(GFSK)_2 441 MHz_DH5	BDR(π/4DQPSK)_2 441 MHz_DH5
	

Dwell time	
EDR(8DPSK)_2 441 MHz_DH1	-
	-
EDR(8DPSK)_2 441 MHz_DH3	-
	-
EDR(8DPSK)_2 441 MHz_DH5	-
	-

6.7 Spurious Emission, Band edge and Restricted Bands

6.7.1 Regulation

§15.247(d) : In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

§15.209(a) : Except as provided elsewhere in this subpart, the emissions from an intentional radiator shall not exceed the field strength levels specified in the following table:

Frequency (MHz)	Field strength (microvolts/meter)	Measurement distance (meters)
0.009-0.490	2400/F(kHz)	300
0.490-1.705	24000/F(kHz)	30
1.705-30.0	30	30
30-88	100**	3
88-216	150**	3
216-960	200**	3
Above 960	500	3

**Except as provided in paragraph (g), fundamental emissions from intentional radiators operating under this section shall not be located in the frequency bands 54-72 MHz, 76-88 MHz, 174-216 MHz or 470-806 MHz. However, operation within these frequency bands is permItted under other sections of this part, e.g., §§15.231 and 15.241.

§15.205(a) : Except as shown in paragraph (d) of this section, only spurious emissions are permitted in any of the frequency bands listed below:

MHz	MHz	MHz	GHz
0.090-0.110	16.42-16.423	399.9-410	4.5-5.15
[1]0.495-0.505	16.69475-16.69525	608-614	5.35-5.46
2.1735-2.1905	16.80425-16.80475	960-1240	7.25-7.75
4.125-4.128	25.5-25.67	1300-1427	8.025-8.5
4.17725-4.17775	37.5-38.25	1435-1626.5	9.0-9.2
4.20725-4.20775	73-74.6	1645.5-1646.5	9.3-9.5
6.215-6.218	74.8-75.2	1660-1710	10.6-12.7
6.26775-6.26825	108-121.94	1718.8-1722.2	13.25-13.4
6.31175-6.31225	123-138	2200-2300	14.47-14.5
8.291-8.294	149.9-150.05	2310-2390	15.35-16.2
8.362-8.366	156.52475-156.52525	2483.5-2500	17.7-21.4
8.37625-8.38675	156.7-156.9	2690-2900	22.01-23.12
8.41425-8.41475	162.0125-167.17	3260-3267	23.6-24.0
12.29-12.293	167.72-173.2	3332-3339	31.2-31.8
12.51975-12.52025	240-285	3345.8-3358	36.43-36.5
12.57675-12.57725	322-335.4	3600-4400	([2])
13.36-13.41			

1Until February 1, 1999, this restricted band shall be 0.490-0.510 MHz.

2Above 38.6

§15.205 (b) : Except as provided in paragraphs (d) and (e) of this section, the field strength of emissions appearing within these frequency bands shall not exceed the limits shown in §15.209. At frequencies equal to or less than 1000 MHz, compliance with the limits in §15.209 shall be demonstrated using measurement instrumentation employing a CISPR quasi-peak detector. Above 1000 MHz, compliance with the emission limits in §15.209 shall be demonstrated based on the average value of the measured emissions. The provisions in §15.35 apply to these measurements.

6.7.2 Test Procedure

Spurious RF Conducted Emissions

Connect the primary antenna port through an attenuator to the spectrum analyzer input; in the results,account for all losses between the unlicensed wireless device output and the spectrum analyzer. The instrument shall span 30 MHz to 10 times the operating frequency in GHz, with a resolution bandwidth of 100 kHz, video bandwidth of 300 kHz, and a coupled sweep time with a peak detector. The band 30 MHz to the highest frequency may be split into smaller spans, as long as the entire spectrum is covered.

Spurious Radiated Emissions

1. The preliminary radiated measurement were performed to determine the frequency producing the maximum emissions in an semi-anechoic chamber at a distance of 3 meters.
2. The EUT was placed on the top of the 0.8-meter height, 1 x 1.5 meter non-metallic table. To find the maximum emission levels, the height of a measuring antenna was changed and the turntable was rotated 360º.
3. The antenna polarization was also changed from vertical to horizontal. The spectrum was scanned from 9 kHz to 30 MHz using the loop antenna, and from 30 to 1000 MHz using the Bi-Log antenna, and from 1000 MHz to 26500 MHz using the horn antenna.

4. To obtain the final measurement data, the EUT was arranged on a turntable situated on a 4 x 4 meter in an semi-anechoic chamber. The EUT was tested at a distance 3 meters.
5. Each frequency found during preliminary measurements was re-examined and investigated. The test-receiver system was set up to average, peak, and quasi-peak detector fuction with specified bandwidth.
6. The 0.8 m height is for below 1 GHz testing, and 1.5 m is for above 1GHz testing.

- Procedure for unwanted emissions measurements below 1 000 MHz

a) The procedure for unwanted emissions measurements below 1 000 MHz is as follows:
   1) Analyzer center frequency was set to the frequency of the radiated spurious emission of interest
   2) RBW =

Frequency	RBW
9 kHz to 150 kHz	200 Hz to 300 Hz
0.15 MHz to 30 MHz	9 kHz to 10 kHz
30 MHz to 1000 MHz	100 kHz to 120 kHZ

   3) Detector = CISPR Quasi-peak
   4) Sweep time = auto couple
   5) Compliance shall be determined using CISPR quasi-peak detection; however, peak detection is permitted as an alternative to quasi-peak detection

- Procedure for peak unwanted emissions measurements above 1 000 MHz

The procedure for peak unwanted emissions measurements above 1 000 MHz is as follows:

a) Peak emission levels are measured by setting the instrument as follows:
   1) RBW = 1 MHz
   2) VBW ≥ [3 × RBW]
   3) Detector = peak
   4) Sweep time = auto
   5) Trace mode = max hold
   6) Allow sweeps to continue until the trace stabilizes. Note that if the transmission is not continuous, then the time required for the trace to stabilize will increase by a factor of pproximately 1 / D, where D is the duty cycle. For example, at 50 % duty cycle, the easurement time will increase by a factor of two, relative to measurement time for ontinuous transmission

- Procedure for average unwanted emissions measurements above 1 000 MHz

From the peak value of the emission :
The measured peak value in dBμV/m is corrected by 20log(maximum dwell time in 100 ms / 100)

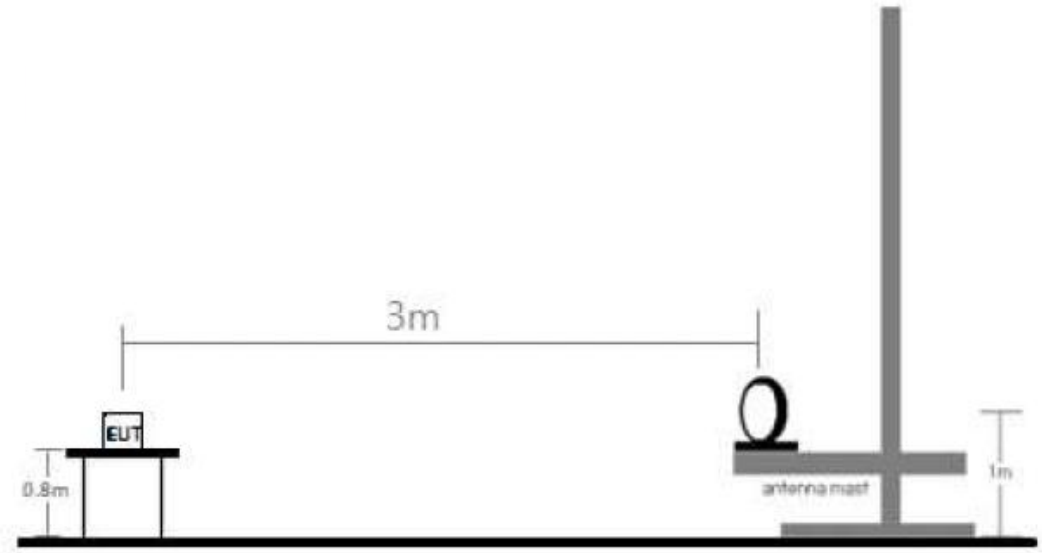
- Sample Calculation

- Field Strength Level [dBμV/m] = Analyzer Level [dBm] + 107 + AFCL [dB/m] + Duty Cycle Correction [dB]
- AFCL [dB/m] = Antenna Factor [dB/m] + Cable loss [dB]
- Margin [dB] = Field Strength Level [dBμV/m] – Limit [dBμV/m]

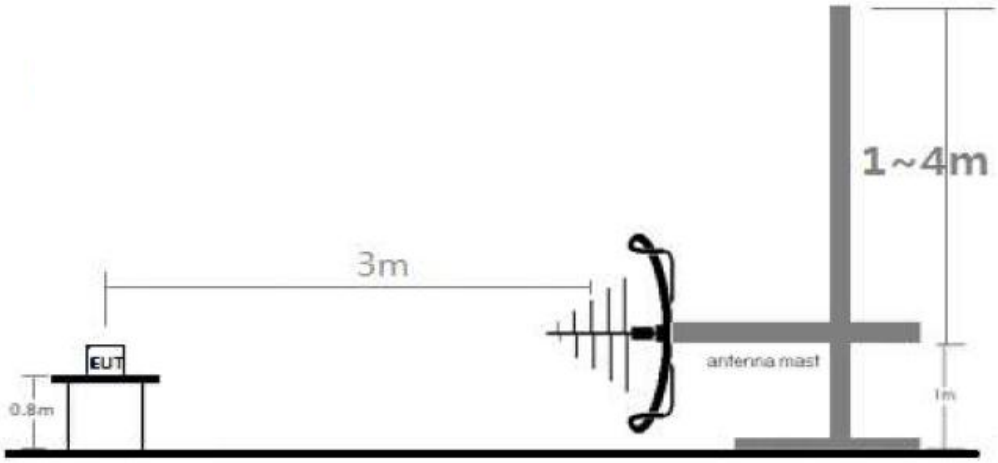
- Duty Cycle Correction Factor Calculation - worst

- Channel hop rate = 800 hops/second
- Adjusted channel hop rate for DH5 mode = 133.33 hops/second
- Time per channel hop = 1 / 133.33 hops/second = 7.50 ms
- Time to cycle through all channels = 7.50 x 20 channels = 150 ms
- Number of times transmitter hits on one channel = 100 ms / 150 ms = 1 time(s)
- Worst case dwell time = 7.5 ms
- Duty cycle correction factor = $20\log_{10}$(7.5 ms / 100 ms) = -22.5 dB

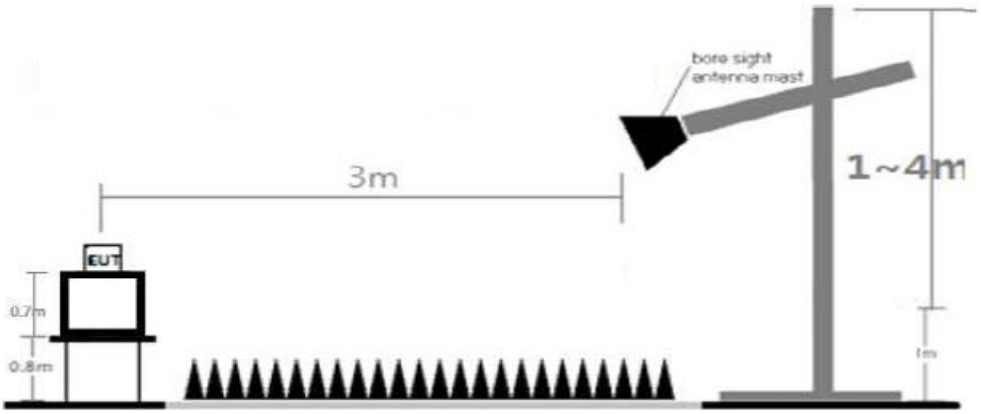
6.7.3 Test Setup

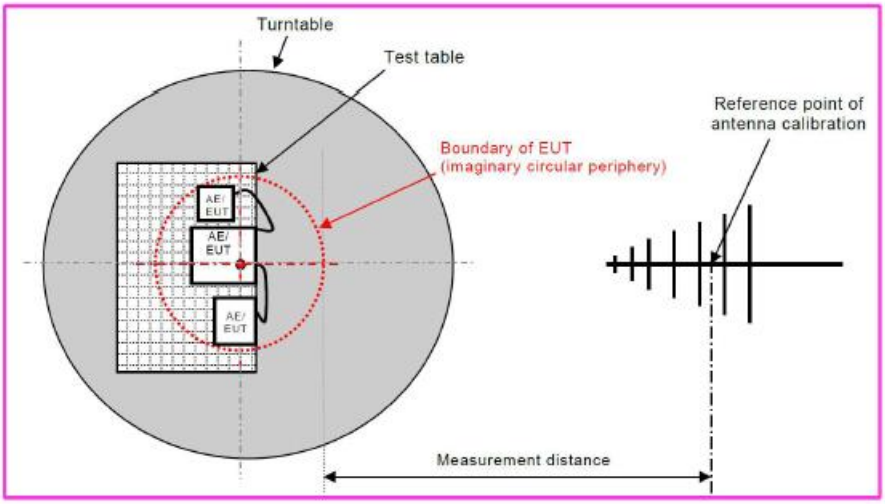


[Radiated Emission Test Setup Below 30 MHz]

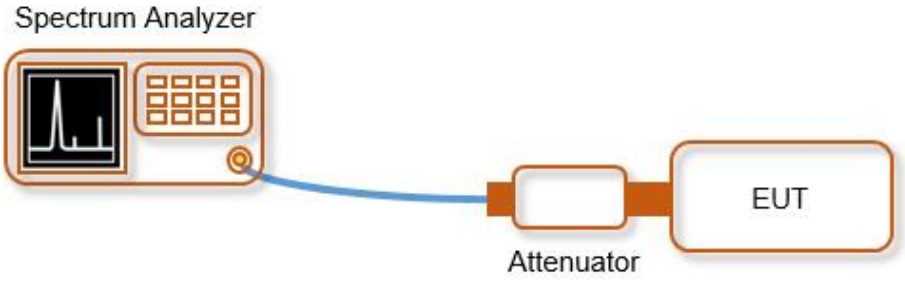


[Radiated Emission Test Setup Below 1 GHz]





[Radiated Emission Test Setup Above 1 GHz]

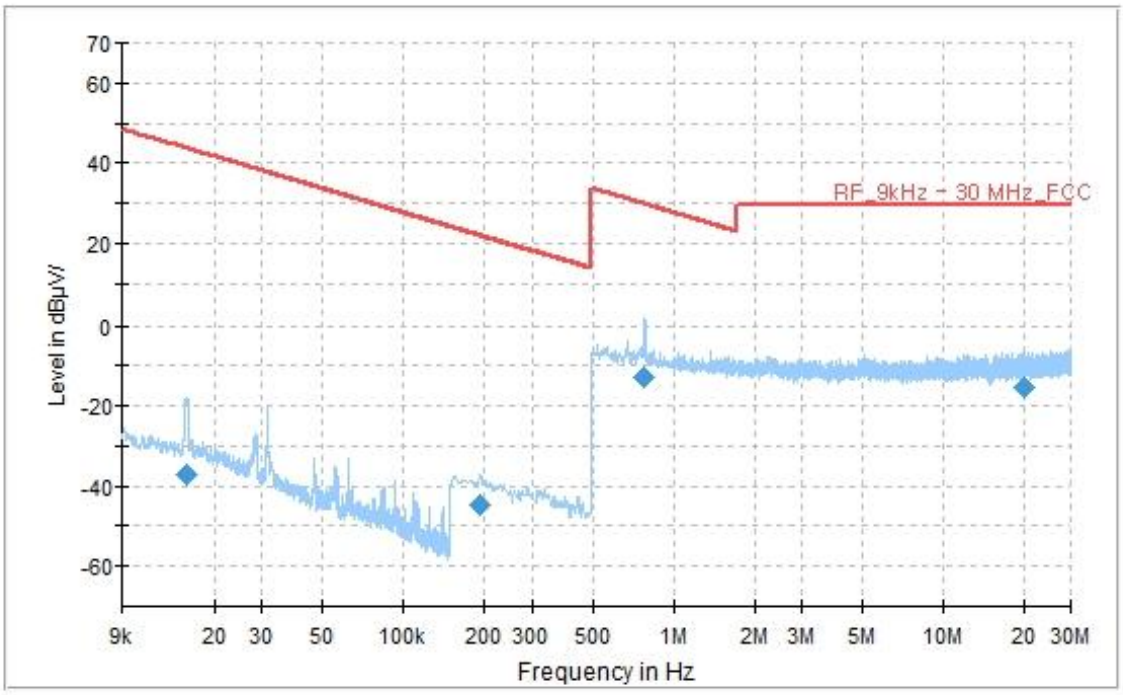


[Conducted Spurious Emission]

6.7.4 Test Result

Radiated Emission (Below 30 MHz)

Worst case - RE(Below 30 MHz)_EDR_2 402 MHz



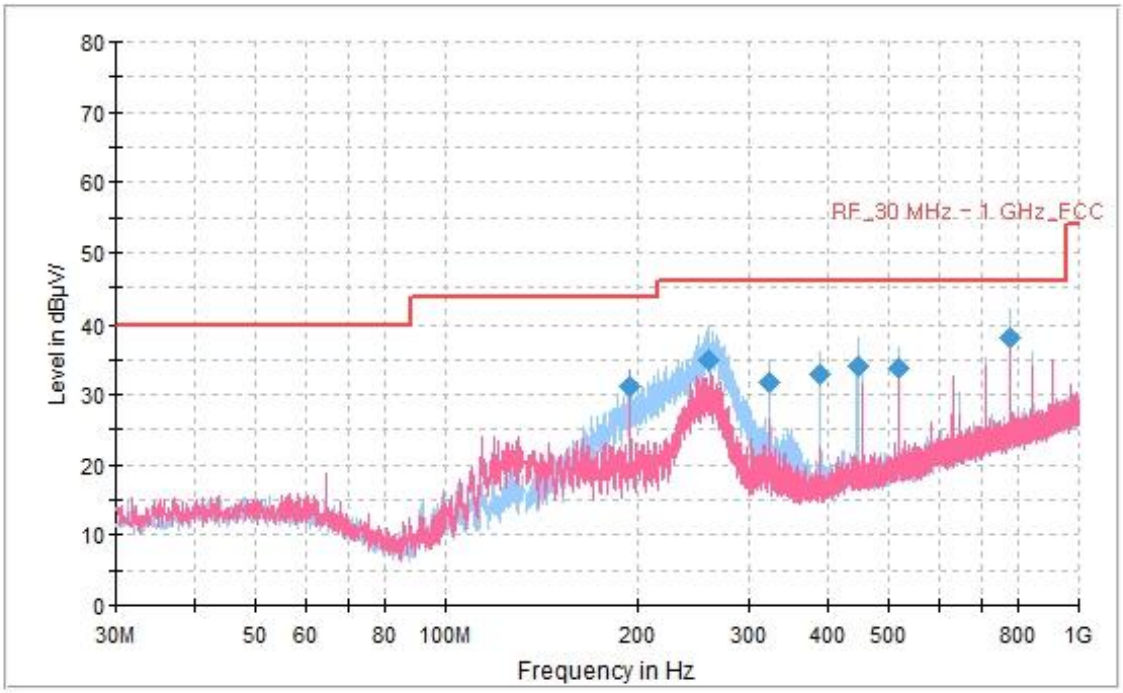
Frequency [MHz]	Quasi-peak Reading [dBuV]	Quasi-Peak Result [dBuV/m]	Distance Factor [dB]	Limit [dBuV/m]	Margin [dB]	Height [cm]	Pol	Azimuth [deg]	Corrction Factor [dB/m]
0.016	22.26	-37.14	-80	43.65	80.79	100	Parallel	184	-59.40
0.195	14.61	-44.79	-80	21.81	66.60	100	Parallel	293	-59.40
0.781	6.19	-13.11	-40	29.76	42.86	100	Parallel	153	-19.30
20.014	2.61	-15.49	-40	29.54	45.03	100	Parallel	253	-18.10

Note)

1. Quasi Peak(dBuV/m) = QP Reading Value(dBµV) + Correction Factor(dB/m) + Distance Factor(dB)
2. Correction Factor(dB) = Antenna Factor(dB/m) + Cable Factor(dB) – Pre-Amplifier Factor(dB)
3. Margin(dB) = (Quasi Peak) Limit (dBµV/m) – (Quasi Peak) Result (dBµV/m)
4. We tested three kind of Antenna Pol (Parallel, Perpendicular, Ground parallel) and reported worst case antenna Pol.

Radiated Emission (Below 1 GHz)

Worst case - RE(Below 1 GHz)_EDR_2 402 MHz

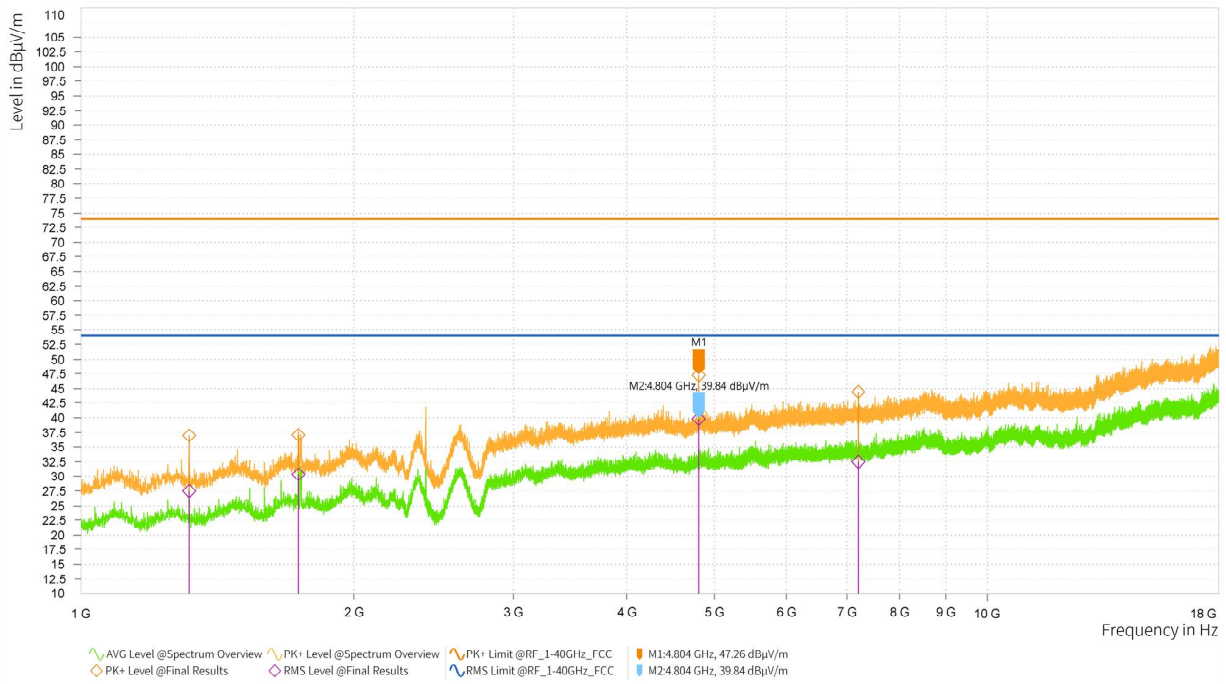


Frequency [MHz]	Quasi-Peak Reading [dBuV]	Quasi-Peak Result [dBuV/m]	Limit [dBuV/m]	Margin [dB]	Height [cm]	Pol	Azimuth [deg]	Corrction Factor [dB/m]
194.253	41.53	31.33	43.52	12.19	100	V	335	-10.20
258.597	42.90	35.00	46.02	11.02	100	H	47	-7.90
323.641	37.38	31.88	46.02	14.14	100	H	145	-5.50
388.469	36.79	32.99	46.02	13.03	100	H	161	-3.80
445.753	36.23	34.13	46.02	11.89	200	H	147	-2.10
517.910	34.60	33.80	46.02	12.22	100	H	254	-0.80
777.008	33.86	38.16	46.02	7.86	200	H	195	4.30

Note)
1. Quasi Peak(dBµV/m) = Quasi Peak Reading Value(dBµV) + Correction Factor(dB/m)
2. Correction Factor(dB) = Antenna Factor(dB/m) + Cable Factor(dB) – Pre-Amplifier Factor(dB)
3. Margin(dB) = (Quasi Peak) Limit (dBµV/m) – (Quasi Peak) Result (dBµV/m).

Radiated Emission (Above 1 GHz)

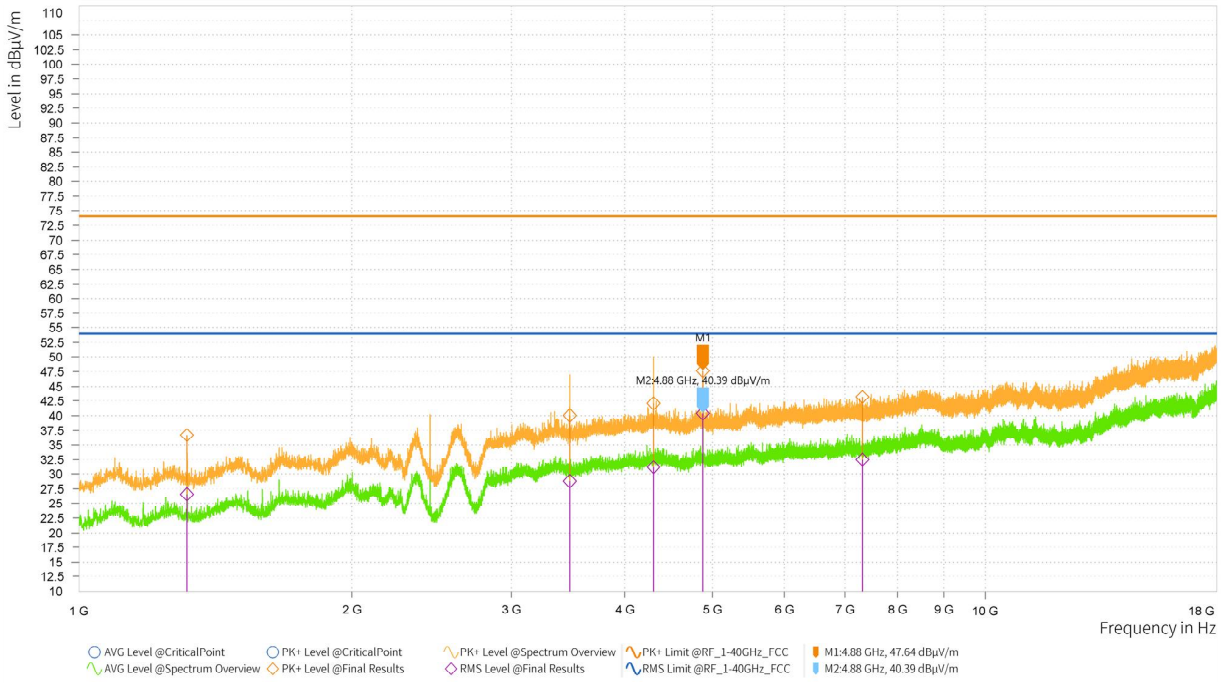
RE(Above 1 GHz)_BDR_2 402 MHz



	Frequency [MHz]	Peak Reading [dBuV]	Peak Result [dBuV/m]	AVG Reading [dBuV]	AVG Result [dBuV/m]	DCCF [dB]	Height [cm]	Pol	Azimuth [deg]	Corr. [dB/m]	Peak Margin [dB]	Peak Limit [dBuV/m]	AVG Margin [dB]	AVG Limit [dBuV/m]
	1 316.500	52.72	37.00	-	14.50	-22.50	2.00	V	305.9	-15.72	37.00	74.00	39.50	54.00
	1 737.500	50.41	37.07	-	14.57	-22.50	2.00	V	262.0	-13.34	36.93	74.00	39.43	54.00
*	4 803.500	50.07	47.26	-	24.76	-22.50	2.00	H	142.0	-2.81	26.74	74.00	29.24	54.00
	7 206.000	44.20	44.45	-	21.95	-22.50	3.00	H	322.3	0.25	29.55	74.00	32.05	54.00

Note)
1. Peak Result(dBuV/m) = Peak Reading Value(dBuV) + Correction Factor(dB/m)
2. AVG Result(dBuV/m) = Peak Result(dBuV/m) + DCCF(dB)
3. DCCF(Duty Cycle Correction Factor) = 20 x Log(worst dwell time/100 ms)
4. Correction Factor(dB/m) = Antenna Factor(dB/m) + Cable Factor(dB) – Pre-Amplifier Factor(dB) + Distance Factor (dB)
5. Margin(dB) = (Peak/AVG) Limit (dBuV/m) – (Peak/AVG) Result (dBuV/m)
6. * - indicates frequency in Restricted Band.

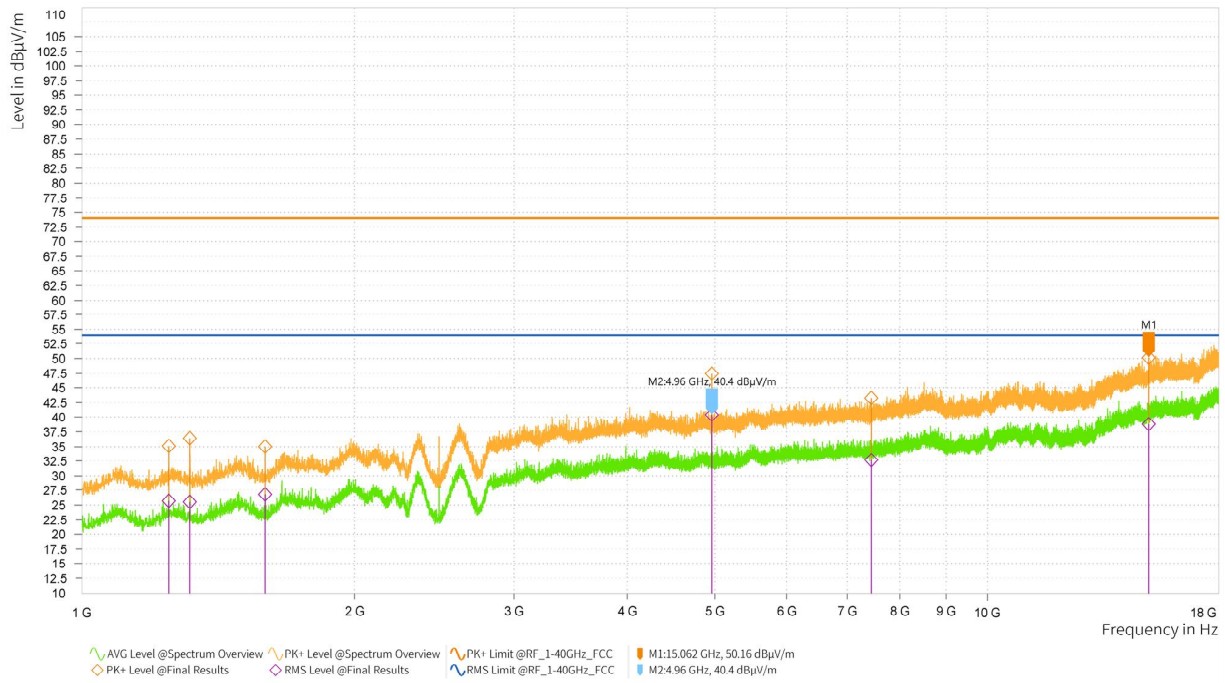
RE(Above 1 GHz)_BDR_2 441 MHz



	Frequency [MHz]	Peak Reading [dBuV]	Peak Result [dBuV/m]	AVG Reading [dBuV]	AVG Result [dBuV/m]	DCCF [dB]	Height [cm]	Pol	Azimuth [deg]	Corr. [dB/m]	Peak Margin [dB]	Peak Limit [dBuV/m]	AVG Margin [dB]	AVG Limit [dBuV/m]
	1 316.000	52.40	36.67	-	14.17	-22.50	2.00	H	92.0	-15.73	37.33	74.00	39.83	54.00
	3 479.000	46.02	40.04	-	17.54	-22.50	3.00	V	143.5	-5.98	33.96	74.00	36.46	54.00
*	4 303.500	45.62	42.06	-	19.56	-22.50	2.00	V	317.6	-3.56	31.94	74.00	34.44	54.00
*	4 879.500	50.11	47.64	-	25.14	-22.50	2.00	H	151.9	-2.47	26.36	74.00	28.86	54.00
*	7 320.000	43.11	43.20	-	20.70	-22.50	3.00	V	329.2	0.09	30.80	74.00	33.30	54.00

Note)
1. Peak Result(dBuV/m) = Peak Reading Value(dBuV) + Correction Factor(dB/m)
2. AVG Result(dBuV/m) = Peak Result(dBuV/m) + DCCF(dB)
3. DCCF(Duty Cycle Correction Factor) = 20 x Log(worst dwell time/100 ms)
4. Correction Factor(dB/m) = Antenna Factor(dB/m) + Cable Factor(dB) – Pre-Amplifier Factor(dB) + Distance Factor (dB)
5. Margin(dB) = (Peak/AVG) Limit (dBuV/m) – (Peak/AVG) Result (dBuV/m)
6. * - indicates frequency in Restricted Band.

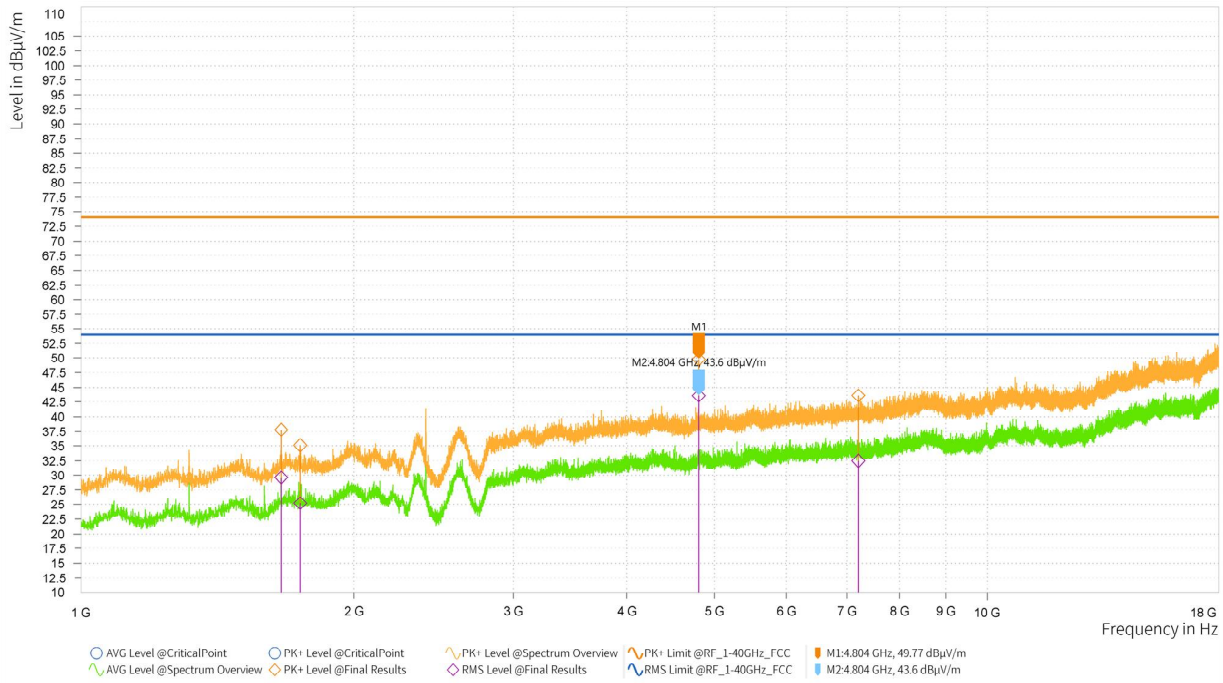
RE(Above 1 GHz)_BDR_2 480 MHz



	Frequency [MHz]	Peak Reading [dBuV]	Peak Result [dBuV/m]	AVG Reading [dBuV]	AVG Result [dBuV/m]	DCCF [dB]	Height [cm]	Pol	Azimuth [deg]	Corr. [dB/m]	Peak Margin [dB]	Peak Limit [dBuV/m]	AVG Margin [dB]	AVG Limit [dBuV/m]
	1 247.000	51.01	35.15	-	12.65	-22.50	3.00	H	118.7	-15.86	38.85	74.00	41.35	54.00
	1 316.000	52.15	36.42	-	13.92	-22.50	2.00	V	105.0	-15.73	37.58	74.00	40.08	54.00
*	1 593.500	49.03	35.05	-	12.55	-22.50	2.00	H	360.0	-13.98	38.95	74.00	41.45	54.00
*	4 959.500	49.81	47.46	-	24.96	-22.50	2.00	H	159.7	-2.35	26.54	74.00	29.04	54.00
*	7 440.000	43.18	43.30	-	20.80	-22.50	3.00	H	146.4	0.12	30.70	74.00	33.20	54.00
	15 062.000	42.86	50.16	-	27.66	-22.50	3.00	H	104.6	7.30	23.84	74.00	26.34	54.00

Note)
1. Peak Result(dBuV/m) = Peak Reading Value(dBuV) + Correction Factor(dB/m)
2. AVG Result(dBuV/m) = Peak Result(dBuV/m) + DCCF(dB)
3. DCCF(Duty Cycle Correction Factor) = 20 x Log(worst dwell time/100 ms)
4. Correction Factor(dB/m) = Antenna Factor(dB/m) + Cable Factor(dB) – Pre-Amplifier Factor(dB) + Distance Factor (dB)
5. Margin(dB) = (Peak/AVG) Limit (dBuV/m) – (Peak/AVG) Result (dBuV/m)
6. * - indicates frequency in Restricted Band.

RE(Above 1 GHz)_EDR_2 402 MHz



	Frequency [MHz]	Peak Reading [dBuV]	Peak Result [dBuV/m]	AVG Reading [dBuV]	AVG Result [dBuV/m]	DCCF [dB]	Height [cm]	Pol	Azimuth [deg]	Corr. [dB/m]	Peak Margin [dB]	Peak Limit [dBuV/m]	AVG Margin [dB]	AVG Limit [dBuV/m]
*	1 663.000	51.40	37.83	-	15.33	-22.50	2.00	H	138.5	-13.57	36.17	74.00	38.67	54.00
	1 745.000	48.43	35.10	-	12.60	-22.50	3.00	V	217.4	-13.33	38.90	74.00	41.40	54.00
*	4 804.000	52.58	49.77	-	27.27	-22.50	2.00	H	170.3	-2.81	24.23	74.00	26.73	54.00
	7 206.000	43.36	43.61	-	21.11	-22.50	2.00	V	70.9	0.25	30.39	74.00	32.89	54.00

Note)
1. Peak Result(dBuV/m) = Peak Reading Value(dBuV) + Correction Factor(dB/m)
2. AVG Result(dBuV/m) = Peak Result(dBuV/m) + DCCF(dB)
3. DCCF(Duty Cycle Correction Factor) = 20 x Log(worst dwell time/100 ms)
4. Correction Factor(dB/m) = Antenna Factor(dB/m) + Cable Factor(dB) – Pre-Amplifier Factor(dB) + Distance Factor (dB)
5. Margin(dB) = (Peak/AVG) Limit (dBuV/m) – (Peak/AVG) Result (dBuV/m)
6. * - indicates frequency in Restricted Band.